Cretaceous ammonites from Upper Austria

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Abstract: Lower Cretaceous ammonite faunas from Upper Austria are presented. Lithological, sedimentological and palaeoecological studies over the last decade of the Lower Cretaceous (Northern Calcareous Alps, Upper Austria) uncovered rich spectra of Valanginian-Barremian ammonites. Distinct ammonite faunas derive from limestones, marls and sandstones of well know tectonical nappes from Upper Austria (e.g. Ternberg Nappe, Reichraming Nappe, Staufen-Höllengebirgs Nappe, Langbath Unit). The main sections are, from north to south, the KB1-A Klausrieglerbach 1 section (Schrambach Formation), the KB1-B Klausrieglerbach 2 section (Schrambach Formation), the Hirner section (Schrambach Formation), the Eibeck Section (Rossfeld Formation), the Hochkogel section (Rossfeld Formation), the Traunkirchen section (Tannheim Formation) and the Kolowratshöhe section (Rossfeld Formation).
Thousands of ammonite specimens were collected, prepared and described. The ammonite assemblages clearly indicate a Mediterranean character with intermittent short pulses of Boreal immigrants. The composition of the ammonite assemblages is clearly linked to environmental changes during Lower Cretaceous stages. Sea level changes and variations in climate triggered the evolution of ammonite species. The palaeontological studies on the Lower Cretaceous ammonite material increased the knowledge on palaeoceanographic and palaeoenvironmental conditions at the time of formation of the Northern Calcareous Alps in Upper Austria. The intermittent palaeogeographic situation of the Northern Calcareous Alps during the Lower Cretaceous serves as a key for understanding the ammonite distribution in the Mediterranean Realm.

Keywords: Ammonites, palaeontology, geology, Lower Cretaceous, Northern Calcareous Alps, Upper Austria

Introduction

Lower Cretaceous pelagic sediments are well known to form a major element of the northernmost tectonic units of the Northern Calcareous Alps (e.g. Ternberg-, Reichraming-, Frankenfels-, Lunz-, Staufen- and Höllengebirgs nappes). As noted by numerous authors (VAŠÍČEK & MICHALÍK 1999; STAMPFLI & MOSAR 1999; SCOTESE 2001; WAGREICH et al. 2008), the area investigated (Northern Calcareous Alps) was situated at the eastern border of the Alpine-Carpathian Block during the Early Cretaceous. This was located between the Penninic Ocean in the North and the Vardar Ocean (= Meliata Ocean) in the South-East.

In the Northern Calcareous Alps, Valanginian to Barremian cephalopod-bearing deposits are mainly recorded in two different facies, the Schrambach and the Rossfeld Formation (PILLER et al. 2004; WAGREICH et al. 2008). Additionally the Aptian-Albian Tannheim Formation and the Albian Losenstein Formation in can occur in the lower Bajuvaric units (PILLER et al. 2004). Lower Cretaceous sediments of the Valanginian-Barremian Rossfeld Formation comprise turbiditic marls and sandstones, whereas the Valanginian-Aptian Schrambach Formation consist limestones and marly limestones, with in its lower parts frequent turbiditic sandstone intercalations (VAŠÍČEK & FAUPL 1996). The Schrambach Formation occurs in both, the lower and the upper Bajuvaric units. Contrastingly the siliciclastic Rossfeld Formation is characteristic for the higher Bajuvaric units to the south. The limestones and marly limestones of the Schrambach Formation are typical sediments of pelagic to hemiopalagic enviroments based on the sedimentation of calcareous muds and oozes in deeper waters of the Penninic Ocean at that time. The source area for the Rossfeld Formation and the sandstone intercalations of the Schrambach Formation was situated to the south of the basin (FAUPL 1979; FAUPL & WAGREICH 1992; VAŠÍČEK & FAUPL 1996, 1998; EGGER et al. 2011). The Rossfeld Formation is restricted to southern parts of the nappes. It is interpreted as a synorogenic succession deposited at the beginning of the compressional deformation within the Austroalpine unit (FAUPL 1979; DECKER et al. 1987). The palaeogeographical reconstruction of the investigated area through the Lower Cretaceous shows that the sedimentation of these turbiditic sediments, in the internal and eastern parts of the Northern Calcareous Alps (southern parts of the 'Bajuvarikum') is apparently connected with an uplift of the southernmost parts. The thickness of Lower Cretaceous sediments occurring in the northern tectonic units of the NCA decreases to-

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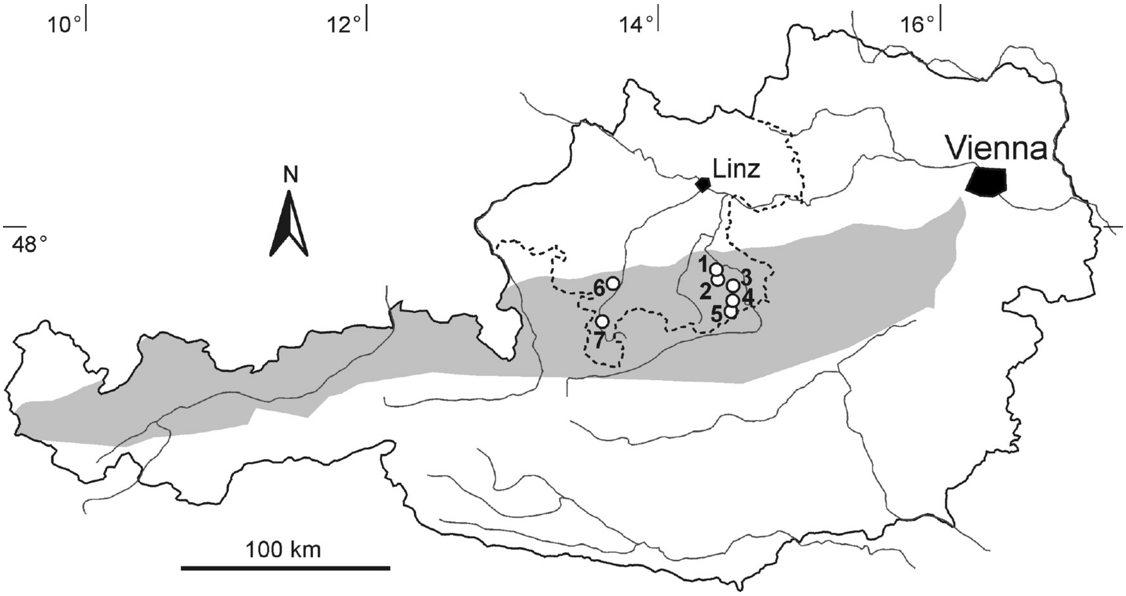


Fig. 1: Locality map of Austria showing the Lower Cretaceous outcrops (white circles) within the Northern Calcareous Alps (grey). 1. KB1-A Klausrieglerbach 1 section (Schrambach Formation), 2. KB1-B Klausrieglerbach 2 section (Schrambach Formation), 3. Hirner section (Schrambach Formation), 4. Eibeck Section (Rossfeld Formation), 5. Hochkogel section (Rossfeld Formation), 6. Traunkirchen section (Tannheim Formation), 7. Kolowratshöhe section (Rossfeld Formation).

wards the north. Geodynamical processes occurring within the basins involved were reviewed by FAUPL & WAGREICH (2000). The dominating sandstone deposits within the Tyrolic Unit (e.g. Rossfeld Formation) become less prominent within northern nappes (e.g. Bajuvaric units; PILLER et al. 2004). This reflects either beginning subduction of the Penninic Ocean in the North or the obduction of oceanic crust of the former Vardar Ocean at the boundary Austroalpine/Southern Alps (SCHLAGINTWEIT 1991). The Eastern Alps originated within the northwestern Tethys palaeogeographic belt due to repeated convergence between the European and the African plate and intervening microplates. A Jurassic-Cretaceous, 'Eoalpine' orogeny was followed by Meso- and Neoalpine deformational events (FAUPL & WAGREICH 2000).

The Austro-Alpine units are a characteristic unit of the Eastern Alps. Based on palaeomagnetic data the Austro-Alpine domain is considered to be a partly independent microplate situated along the northern margin of the Adriatic (Apulian) plate, and represents the northern tip of continental fragments of African affinity during the Cretaceous (STAMPFLI & MOSAR 1999; STAMPFLI & BOREL 2002). Eoalpine deformation strongly influenced Cretaceous sedimentation and the formation of sedimentary basins within of the Austro-Alpine domain (WAGREICH et al. 2008). Thus, a complex history of synorogenic basins with strongly varying geometries and short-lived subsidence and uplift events characterizes the Austro-Alpine realm, especially during mid- and Late Cretaceous times. The best documented Cretaceous successions of the Austro-Alpine domain are preserved within the Northern Calcareous Alps (NCA, Fig. 1). Cretaceous deformation resulted in thrusting and faulting within the NCA (WAGREICH et al. 2008).

Within the Northern Calcareous Alps deep-water carbonate and marls predominate in the Lower Cretaceous. Synorogenic clastic successions and marl facies of the Lower Cretaceous comprises Maiolica-type limestones at their base grading into a shale-limestone cyclic facies. Resedimented clasts of shallow-water Urgonian-type carbonates (SCHLAGINTWEIT 1991) give evidence that small carbonate platforms were present in northern parts of the NCA during the Early Cretaceous, but were later completely eroded. The deposits are interpreted as pelagic sediments of the deep-water shelf to slope of the passive margin of the Austroalpine microplate. The onset of siliciclastic synorogenic strata marked the change to a tectonically active margin due to compression at the Austroalpine-Penninic margin (WAGREICH 2003; WAGREICH et al. 2008).

The Kimmeridgian - Early Berrasian Oberalm Formation represents a pelagic deep-water limestone with grey, cherty, bedded micrites including carbonate turbidites of varying thicknesses. The microfauna is dominated by radiolarians, calpionellids and foraminifera (WEIDICH 1990; REHÁKOVÁ et al. 1996; BOOROVÁ et al. 1999). Turbiditic Barmstein Limestone beds within the Oberalm Formation contain a diverse fauna of calcareous algae and foraminifera indicating an early Berriasian age. The Upper Jurassic to Berriasian carbonate platforms of the Plassen Formation (SCHLAGINTWEIT & EBLI 1999; GAWLICK et al. 2006) can be regarded as the source for the resedimented shallow-water material.

The Oberalm Formation grades into grey micritic limestones and limestone-marl rhythmites of the Schrambach Formation (VAŠÍČEK & FAUPL 1999; RASSER et al. 2003; LUKENEDER 1997, 1998, 2000; Aptychus limestone and Ammergau Formation p.p. of some authors) during the Berriasian. Sandy turbidites are large-

ly absent in the Schrambach Formation, and the amount of marl intercalations increases upwards. Considering different tectonic units of the NCA both the base and especially the top of the Schrambach Formation are diachronous.

In more internal nappe complexes of the NCA (Tirolic units west and south of Salzburg; Reichraming and Lunz nappes further to the east), deep-water limestones graded into synorogenic terrigenous facies of the Rossfeld Formation during Valanginian to Aptian time (DECKER et al. 1987; VAŠÍČEK & FAUPL 1998). The Rossfeld basin is interpreted as a deep-water foreland to piggyback trough in front of overthrusting higher NCA-nappes (DECKER et al. 1987). The Rossfeld Formation comprises a coarsening upward succession of marls and sandstones, grading into deep-water conglomerates/breccias as well as slump deposits sedimented on an active north-facing slope. The sandstones contain considerable amounts of siliciclastic and ophiolitic detritus from southern source terrains, including chrome spinels from ophiolites of the Tethys-Vardar-Hallstatt suture (POBER & FAUPL 1988; VON EYNATTEN & GAUPP 1999).

The stratigraphy of the Lower Cretaceous sediments within the Northern Calcareous Alps around the investigated areas is based on ammonoids. During the last two decades, a rich cephalopod fauna was collected from Lower Cretaceous sediments (IMMEL 1987; VAŠÍČEK & FAUPL 1996, 1998, 1999; VAŠÍČEK et al. 1994; FAUPL et al. 2003).

The present contribution provides a detailed study of the rich and extraordinarily well-preserved Lower Cretaceous ammonoid faunas from various sections of Upper Austria, which yields new and important biostratigraphical data, and presents a compilation of ammonite faunas and facies within the Northern Calcareous Alps. Lower Cretaceous cephalopod faunas (i.e. ammonites, aptychi and belemnites) and facies described herein are given in detail within numerous papers of LUKENEDER (1997, 1998, 1999, 2000, 2001a, b, c, d, 2002a, b, c, d, 2003a, b, c, 2004a, b, c, d, 2005a, b, c, d, e), LUKENEDER & HARZHAUSER (2002, 2003), LUKENEDER & TANABE (2002), and LUKENEDER & REHÁKOVÁ (2004, 2007).

The main goal of this paper is to present results of the Lower Cretaceous ammonite studies over the last two decades for a broader readership. Case studies on Lower Cretaceous ammonites from Upper Austria were basically performed within two 3-year projects of the Austrian Science Fund (FWF P13641 and P16100).

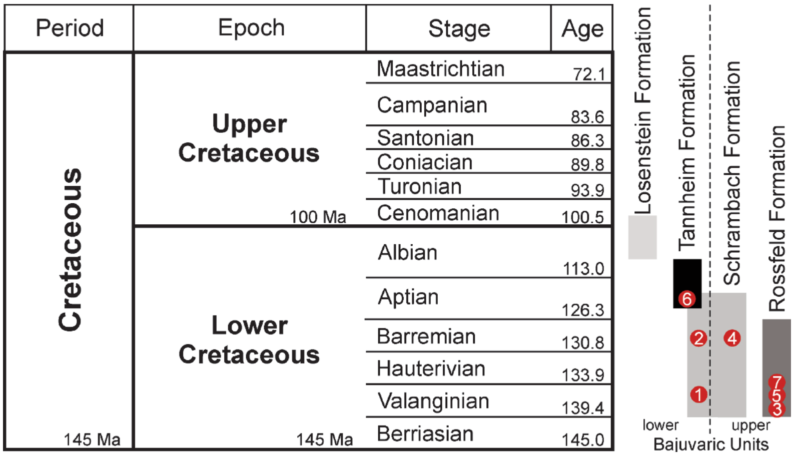


Fig. 2: Stratigraphical index and lithology (modified after GRADSTEIN et al. 2012; PILLER et al. 2004) with the indicated range of the Schrambach Formation, the Rossfeld Formation, the Tannheim Formation and the Losenstein Formation. Numbers are according to localities given in Fig. 1.

Geography and geological setting

The geography and geological situation is summarised for each distinct locality and outcrop. The exact position of the ammonite occurrences is fixed by GPS data (global positioning system). All localities presented are located in Northern Calcareous Alps of Upper Austria. Due to the 'soft' marly lithology of the composing sediments the outcrops are mostly located in morphological synclines. The Losenstein Syncline of the Ternberg Nappe, the Schneeberg Syncline, the Anzenbach Syncline, and the Ebenforst Syncline in the the Reichraming Nappe (from north to south). The Traunkirchen section is located in the Langbath Unit ('Langbath Scholle') with the Hohenau Syncline and the Fahrnau Syncline to the south. The material examined is deposited in the palaeontological collections of the Natural History Museum Vienna.

KB1-A Klausrieglerbach 1 section

The investigated Lower Cretaceous section KB1-A (Klausriegler-Bach 1, Fig. 1) is situated near the Enns River, approximately 1 km southwest, in the Ternberg Nappe (N47°54'32", E14°21'10"). This region is part of the northernmost Northern Calcareous Alps. The Losenstein Syncline is situated in the southernmost part of the Ternberg Nappe (lower Bajuvaric Unit). This syncline is the last syncline to the north filled by Lower Cretaceous sediments. The investigated fossiliferous section is located on the left, nearly vertical (dipping 040/85), step-like wall of the gorge, exposed on a length of 10 m and a height of 5 m.

At the area around Ternberg, the Lower Cretaceous sequence is presented by two different formations from the Steinmühl Formation to the Schrambach Formation (Fig. 2). Steinmühl Formation (approx. 15 m): ear-

ly Berriasian to late early Valanginian in age (LUKENEDER 2000; LUKENEDER & REHÁKOVÁ 2004), its lower part consisting of red ('Ammonitico rosso' type) and its upper part of grey ('Maiolica' type) condensed pelagic limestones with a few ammonoids, but abundant calpionellids and calcareous dinoflagellates enabling precise biostratigraphic correlations. The brachiopod *Pygope cattuloi* is abundant in the topmost bed (LUKENEDER 2002a). Schrambach Formation (approx. 150 m): late Valanginian to late Barremian in age, consisting of pale grey, even bedded limestones intercalated with grey to black calcareous marlstones (laminated 'black shales'), and marls. The beds are intensively bioturbated, and the trace fossils *Zoophycos*, *Chondrites* and *Planolites* occur throughout (LUKENEDER 2001b, 2004a).The wavy boundary between the Steinmühl and the Schrambach Formation is marked by a primary hardground characterized by fragmented, encrusted, and partly eroded ammonoids and several bored cephalopods (e.g. belemnites; LUKENEDER 1999).

KB1-B Klausrieglerbach 2 section

The outcrop is situated in the Ternberg Nappe in Upper Austria approximately 100 m below KB1-A in the same ravine. The exact position is about 7 km west of Losenstein, 1 km south of Kienberg and 500 m southwest of the Klausriegler inn (N47°54'32", E14°21'10", 652 m, ÖK 1:50,000, sheet 69 Großraming, Fig. 1). The stream outcrop crosses the western part of the east-west striking Losenstein Syncline along a line running between the Kreuzmauer (853 m) to the north and the Pfaffenmauer (1218 m) to the south (LUKENEDER 2001b; LUKENEDER & TANABE 2002). The general geological and tectonical features are equal to the described for KB1-A. This section was the starting point for a lateral analysis of the distribution of the reported ammonite mass-occurrence. For detailed descriptions of the investigation area see LUKENEDER (1997, 1998, 1999). The outcrop comprises an ammonite 'mass-occurrence', representing the *Karsteniceras*-Level, is situated in the upper part of the Schrambach Formation (lower Barremian, *Moutoniceras moutonianum* Zone) within the intercalated black calcareous marls (LUKENEDER 2001a, 2003b; LUKENEDER & TANABE 2002 (Fig. 2).

Hochkogel section

The outcrop is situated in the Reichraming Nappe in Upper Austria (LUKENEDER 2005a; LUKENEDER & REHÁKOVÁ 2007). The exact position is about 5 km south of Brunnbach (N47°47'15", E14°30'00", 652 m, ÖK 1:50,000, sheet 69 Großraming, Fig. 1). The outcrop is located in the southernmost part of the east-west striking Ebenforst Syncline along a forest road, running between the Sulzkogel (840 m) to the north and the Hochkogel (1157 m) to the south at the topmost part of the Reixengraben at 885 m. The grey sandstone succession comprising the marly ammonoid-bearing beds (dipping 225/60) is located on the northern side of the Hochkogel, on a nearly vertical wall of the outcrop, which was exposed by road-cutting. The occurrence is exposed in 3 distinct beds of 10–40 cm thickness.

The lower to upper Valanginian cephalopods described here were collected from a little outcrop containing sandstones and marly limestones, located at the southern margin of the Ebenforst Syncline. The Ebenforst Syncline is situated in the southernmost part of the Reichraming Nappe of the Northern Calcareous Alps. This region is part of the higher Bajuvaric Unit, which is neighboured and overlain in the south by the Tyrolian Nappes (Staufen-Höllengebirgs Nappe). The Ebenforst Syncline is followed directly to the north by three additional synclines – the Anzenbach Syncline, the Schneeberg Syncline of the Reichraming Nappe and the Losenstein Syncline of the Ternberg Nappe – all of which are constituted by Lower Cretaceous sediments. The locality is situated 500 m north of the border to the southern Tyrolian Units and is tectonically shifted into the Weyer Arc Structure (LUKENEDER 2005a). The Ebenforst Syncline is formed of a Jurassic sequence (Oberalm Formation, Scheiblberg-Kirchstein Formation, Hierlatzkalk). The core of the Ebenforst Syncline consists of the Lower Cretaceous Rossfeld Formation. The investigated ammonoid 'mass-occurrence' is situated in marly limestones of the Rossfeld Formation (lower to upper Valanginian; LUKENEDER 2005; LUKENEDER & REHÁKOVÁ 2007; Fig. 2).

The terrigenous, proximal, deep-water turbiditic Rossfeld Formation of the Reichraming Nappe represents a synorogenic development. The Rossfeld Formation is mainly composed of grey silty marls accompanied by conglomerates and sandstones. The sandstones are fine, grey calcareous with slump structures. The intercalated marly bioturbated limestones are light-coloured and are associated with a relatively monotonous benthic macrofauna (brachiopods and bivalves). The fabric is burrow-mottled to completely homogenised due to bioturbation and indicates rich benthic colonization. The sedimentological situation at the Hochkogel outcrop differs somewhat from that of other 'Rossfeld Formation' localities. In most cases we find marls or marlstones with intercalated sandstone layers. In contrast to the latter situation, the Rossfeld Formation at the Hochkogel section shows approx. 30 m of fi ne, grey calcareous sandstones (5–50 cm beds) with mass-plant debris on their upper side (LUKENEDER 2005a). Three intercalated limestone beds of 10 to 40 cm thickness (rich in ammonoids) can be distinguished. These limestone beds

are in turn marked by 'small' rhythmically intercalated turbiditic sandstone layers of about 2–3 cm. A short-term sedimentation is proposed for the sandstone layers, whereas the limestones and marl-beds reflect 'normal' sedimentation rates.

Hirner section

The outcrop is situated in the northeastern part of the Reichraming Nappe (Upper Austria), about 3 km southwest of Großraming (446 m, ÖK 1:50,000, sheet 69 Großraming, Fig. 1). The outcrop (640 m) is located in the southeastern-most part of the east-west striking Schneeberg Syncline along a forest road, between the farmhouse Hirner (560 m) to the south and the farmhouse Scharnreitner (580 m) to the north, both situated at the west side of the Lumplgraben (LUKENEDER 2004d).

The limestone succession on the western side at a forest road comprises the ammonoid-bearing beds (dipping 225/80). The material derives from a little outcrop of marly limestones and is located at the southeastern margin of the Schneeberg Syncline (N47°51'47", E14°31'29"; Fig. 2). The Schneeberg Syncline is one of the northernmost parts of the Reichraming Nappe (higher Bajuvaric Unit, Northern Calcareous Alps). It is situated between three more Lower Cretaceous synclines, directly to the north by the Losenstein Syncline of the Ternberg Nappe and to the south the Anzenbach Syncline and the Ebenforst Syncline (Fig. 1). The locality is affiliated with the Upper Cretaceous Gosau Group (20 m to the north and 250 m to the west), which in this area forms of the border of the Weyer Arc Structure. The ammonoid occurrence in the Schrambach Formation (lower Barremian, *Moutoniceras moutonianum* Zone) is composed of marls and marly limestones (about 40 m; LUKENEDER 2004d; Fig. 2). The succession is intercalated by fossiliferous ammonoid-bearing beds. Light-coloured, grey, fine, marly limestones and limestones are associated with a relatively monotonous benthic macrofauna. The pelagic sediments reflect once more 'normal' sedimentation rates.

Eibeckgraben section

The outcrop is situated in the Reichraming Nappe in Upper Austria, about 5 km south of Brunnbach (652 m, ÖK 1:50,000, sheet 69 Großraming; Fig. 1). The stream outcrop is located near the middle of the Eibeckgraben in the south-easternmost part of the eastwest striking Ebenforst Syncline, running between the Sulzkogel (840 m) to the west and the vicinity of the Eibeck (916 m) to the east (LUKENEDER 2004c, 2005b). The succession, comprising the ammonoid-bearing beds, is located on the southern side of the Hochkogel (1157 m). The occurrence is badly exposed on the left side of the stream (N47°47'14", E14°31'00"). Steep terrain and the 'soft nature' of the marly rocks made sampling very difficult.

The upper Valanginian succession of southeastern Upper Austria was deposited in an unstable shelf setting characterized by thick limestone units that reflect transgressive histories punctuated by tectonic events, as shown by the deposition of conglomerates and sandstones (see FAUPL 1979). The terrigenous, proximal, deep-water turbiditic Rossfeld Formation of the Reichraming Nappe represents a synorogenic development (VAŠÍČEK & FAUPL 1998). The Ebenforst Syncline is situated in the southernmost part of the Reichraming Nappe. Three more synclines are present to the north: the Anzenbach Syncline, the Schneeberg Syncline of the Reichraming Nappe, and the Losenstein Syncline of the Ternberg Nappe, all of which consist of Lower Cretaceous sediments in their cores. Lower Cretaceous sediments are represented at the Eibeck section by two formations, the Schrambach Formation (approx. 50 m, Berriasian) and the overlying Rossfeld Formation (approx. 150 m, upper Valanginian, Fig. 2).

Traunkirchen section

During the construction of the Traunkirchen tunnel in Upper Austria, a traffic bypass of Traunkirchen at the Traunsee (Lake Traunsee at the Seestraße, B51; Geological map 1:50,000, sheet 66 Gmunden; see Egger 1996; Fig. 1), an important ammonite could be detected (LUKENEDER 2005c). On a rock blasted wall at 2 meters height (N47°50'35", E13°47'00") several parts of a fossil cephalopod were visible that were not even recognised as belonging to an ammonite at the time of excavation. The ammonite from the Traunkirchen tunnel originates from the lower Aptian beds of the Tannheim Formation (Fig. 2). The Tannheim Formation consists mainly of dark grey and black marly limestones and marls from the Lower Cretaceous. The Lower Cretaceous in this area belongs to the Bajuvaric Zone with the Langbath Unit, a local part of the northern nappes of the Northern Calcareous Alps. The Siegesbachgraben (VAŠÍČEK & SUMMESBERGER 2004) near Traunkirchen and the closely neighboured but tectonically and stratigraphically distant Gschliefgraben are well known.

Kolowratshöhe section

The outcrop is situated in the Staufen-Höllengebirgs Nappe in the southernmost part of Upper Austria, about 3 km southeast of Bad Ischl and 1.5 km east of Perneck (588 m, ÖK 1:50,000, sheet 96 Bad Ischl; see SCHÄFFER 1982; Fig. 1). The succession comprising the

Fig. 3: Ammonites from the upper Valanginian KB1-A Klausrieglerbach 1 section (Schrambach Formation). The dominant species at KB1-A *Olcostephanus* (*Olcostephanus*) *guebhardi* (Kilian) morph. type *querolensis* Bulot. **1**: M, bed 10, 2002z0070/0001. **2**: M and m, bed 4, 2002z0070/0005. **3**: M, bed 4, 2002z0070/ 0004. **4**: m, bed 4, 2002z0070/0002. **5**: M, bed 10, 2002z0070/ 0006. **6**: M+m, m with lappet, bed 29, 2002z0070/0003. All specimens are in natural size and coated with ammonium chloride before photographing. M: macroconch, m: microconch.

ammonoid-bearing beds is located at the end of an old, overgrown forest road on the western side of the Kolowratshöhe (1109 m). The sandstone succession of the Rossfeld Formation is running between the Rettenbach (557 m) to the north and the vicinity of the Salzberg (827 m) to the south (Lukeneder 2005e; Fig. 2). The poor exposure is situated on the left side of the small road (N47°41'24", E13°39'24"). The site can only be accessed with permission from the forest agency, over a steep forest road (approx. 10 km) which has its initial point on the main road from Bad Ischl to Bad Goisern.

The locality is situated in the southernmost part of the Tyrolic Unit, which in this region lies under and/or adjoins the small 'Hallstätter Scholle'. The Tyrolic Unit forms part of the 'Traunalpen Scholle', which in this region represents the westernmost part of the Staufen-Höllengebirgs Nappe (Tollmann 1976).

Lower Cretaceous sediments are represented in the area around the Kolowratshöhe section by two formations, the Rossfeld Formation (approx. 120 m, upper Valanginian) and the Schrambach Formation (approx. 40 m, Hauterivian; LUKENEDER 2005e). The allochthonous slope-trench sediments of the Rossfeld Formation have been divided at the type locality (DECKER et al. 1987) into three different depositional settings: lithofacies A, which is characterized by silty grey marls (approx. 175 m), lithofacies B, characterized by thin to thick bedded sandstones (approx. 120 m) and lithofacies C, characterized by coarse clastics (approx. 50 m).

Lower Cretaceous ammonite assemblages from Upper Austria

KB1-A Klausrieglerbach 1 section

The Lower Cretaceous mass-occurrence of *Olcostephanus* (*Olcostephanus*) *guebhardi* morph. *querolensis* BULOT, 1992 from the upper Valanginian *Saynoceras verrucosum* Zone of the KB1-A section, Ternberg Nappe, the Northern Calcareous Alps (Upper Austria) is described (LUKENEDER 2004a; Fig. 3). This horizon, spanning an interval of almost 3 metres, is interpreted as a longterm accumulation from the water column combined with temporary redeposition from local submarine highs. The fauna of the *Olcostephanus* horizon is composed of 9 genera and 10 species. The *Olcostephanus* mass-occurrence represents a widespread phenomenon. It appears most commonly at oceanographic elevations where olcostephanid shells accumulated on the seafloor during sea-level highs.

No sorting or packing due to sedimentological or biological effects can be observed, whereas concentrations due to subsequent transport or bottom currents can be seen in several beds. An enrichment by redeposition, currents or turbidites is proposed for a few marly layers (e.g. layers 4, 10 and 16) with accumulated fragmented olcostephanids (LUKENEDER 2004a). The olcostephanids were deposited within a phyllocrinid-ophiuroid association. Irregular echinoids proved soft bottom conditions of the secondary allochthonous depositional environment. The mass-occurrence of *Olcostephanus* (*O.*) *guebhardi* morph. *querolensis* (Fig. 3) over an interval of almost 3 metres is interpreted to be the result of a combination of a long-term accumulation from the water column (autochthonous parts) during a favourable time interval and of redepositional phases (allochthonous parts) of the upper Valanginian. The abundant olcostephanids reflect less offshore influences and the proximity of shallow environments (LUKENEDER 2004a). Parts of the *Olcostephanus* horizon show some similarities to a 'Kondensat-Lagerstätte'.

The *Olcostephanus* horizon in the KB1-A section occurs in the transgressive facies, marking a distinct upper Valanginian sea-level rise. This was probably within the upper Valanginian transgression, which also led to a world-wide (e.g. Argentina, Mexico, Colombia, Spain, France, Italy, Switzerland, N. Germany, Austria, Czech Republic, Romania, Bulgaria, Russia, Tunisia, Algeria, South Africa, Madagascar, Pakistan) spreading or even explosion and occupation of new regions (e.g. Boreal Realm) by the *Olcostephanus* group, mostly due to the creation or renewal of seaways. By comparing field evidence and published data from the Vocontian Trough (e.g. BULOT 1993), it seems valid to propose a facies dependence (e.g. depth, outer-inner shelf) of *Olcostephanus* (*O.*) *guebhardi* morph. *querolensis* also for the Austrian KB1-A occurrence (Fig. 3). The descendants are most probably inhabitants of the outer shelf and related areas. It is also suggested that *Olcostephanus* (*O.*) *guebhardi* morph. *querolensis* has its acme within the *verrucosum* Zone, whereas the ancient *Olcostephanus* (*O.*) *guebhardi sensu stricto* is most abundant in the uppermost lower Valanginian (*Busnardoites campylotoxus* Zone) (see BULOT 1992; REBOULET et al. 2009). Comparable occurrences have been recognized by VAŠÍČEK et al. (1994), who (briefly) reported an upper Valanginian 'lumachelle-like' occurrence of *Olcostephanus* and *Haploceras* sp. from the Rossfeld Formation in the Ebenforst Syncline (Upper Austria). The olcostephanid shown in their paper lacks bifurcation of the secondary ribbing and is therefore herein suggested to be an *Olcostephanus* (*O.*) *guebhardi sensu stricto*. Thus, the association described by VAŠÍČEK et al. (1994) is probably older (e.g. ?uppermost lower Valanginian) than the olcostaphanid accumulation of the KB1 section. The extraordinary KB1-A occurrence was most probably formed on an elevation near a sloping ramp that dipped to the south (LUKENEDER 2004a). The redeposited specimens were transported from a nearby deep-water swell.

KB1-B Klausrieglerbach 2 section

A Lower Cretaceous mass-occurrence of ammonites in the Ternberg Nappe of the Northern Calcareous Alps (Upper Austria) is described (LUKENEDER 2001b, 2003b). The mass-occurrence (section KB1-B = Klausrieglerbach 1, section B) dominated by *Karsteniceras ternbergense* LUKENEDER, 2002 is of early Barremian age (*Moutoniceras moutonianum* Zone). The *Karsteniceras* mass-occurrence comprises eight different genera, each apparently represented by a single species, of which four are identified to species level. About 300 specimens of *K. ternbergense* between 5 and 37 mm in diameter were investigated (Fig. 4). Two groups showing thick main ribs but different maximum size are distinguishable. The latter parameters are suggested to reflect sexual dimor-

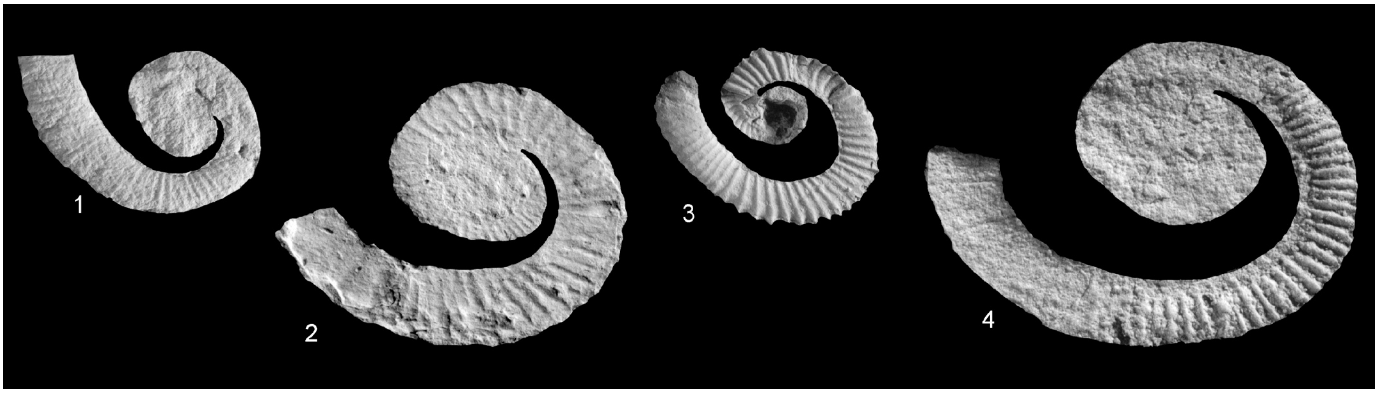


Fig. 4: Ammonites from the lower Barremian KB1-B Klausrieglerbach 2 section (Schrambach Formation). The dominant species at KB1-B *Karsteniceras ternbergense* (LUKENEDER). 1: Holotype of the species *Karsteniceras ternbergense*, bed 22, 2001z0170/0001. 2: *Karsteniceras ternbergense*, bed 18, 2001z0170/0004. 3: *Karsteniceras ternbergense*, thick main ribs on the body chambers, bed 22, 2001z0170/0002. 4: *Karsteniceras ternbergense*, thick main ribs on the body chamber, bed 22, NHMW 2001z0170/0007. All specimens twice their natural size.

phism within *K. ternbergense*, a condition that is most probably applicable to the whole leptoceratoid group. The geochemical results indicate that the *Karsteniceras* mass-occurrence within the described Lower Cretaceous succession was deposited under intermittent oxygen-depleted conditions associated with stable, salinity-stratified water masses. The rhythmicity of laminated black-marly limestone layers and light-grey bioturbated, organic-poor limestones suggests that the oxic and dysoxic conditions underwent highly dynamic changes (LUKENEDER 2003b). The deposition of the limestones in this interval occurred in an unstable environment and was controlled by short- and long-term fluctuations in oxygen levels. *Karsteniceras* (Fig. 4) inhabited areas of stagnant water with low dissolved oxygen; it showed peak abundance during times of oxygen depletion, which partially hindered other invertebrates from settling in such environments. The autochthonous *Karsteniceras* mass-occurrence can be assigned to the deposition-type of 'Konservat-Lagerstätte', which is indicated by the preservation of phosphatic siphuncle structures and proved by the *in situ* preservation of aptychi within *K. ternbergense*. Based on lithological and geochemical analysis combined with investigations of trace fossils, micro fossils and macrofossils, an invasion of an opportunistic (r-strategist) *Karsteniceras* biocoenosis during non favourable conditions over the sea bed during the lower Barremian is proposed for the KB1-B section.

A unique feature in fossil cephalopods was detected from the *Karsteniceras* beds by LUKENEDER & TANABE (2002). Lower Barremian deposits (KB1-B) of Upper Austria yield some extraordinarily preserved ammonoids with *Lamellaptychus* type lower jaws in their body chambers. The ammonoids with *in situ* lower jaws are assignable to *K. ternbergense* (see LUKENEDER & TANABE 2002). This new occurrence was detected during palaeoecological and sedimentological studies at an outcrop in the Ternberg Nappe in Upper Austria. The jaw apparatuses are found in situ or in an isolated condition but are associated with a mass-occurrence of the genus *Karsteniceras*, which contributes 91% of the total ammonite fauna (LUKENEDER 2003b). Most of the lower jaws are flattened, but their characteristic mode of occurrence with conchs of the Tethyan ammonoid *Karsteniceras* allows their use as indicators of palaeobiogeography, palaeobathymetry and palaeoecology.

About five calcified lower jaws (plus horny parts) of *Lamellaptychus*-type appearance were found in split samples of the lower Barremian black to dark grey, laminated limestones of Upper Austria. The morphotype described fits well with morphogroup 5 of TANABE & LANDMAN (2002). These aptychus-type jaws show long commissures and gently arched anterior margins. They are attributed to Cretaceous heteromorphs. All of the specimens derive from two separate beds of *Karsteniceras* level KB1-B, horizons 18 and 22. The rather large sample yielded five aptychi associated with the ammonite *K. ternbergense* along with numerous other ammonites and inoceramids. The lower jaws were found in quite different stages of preservation. In some cases the wings are fragmented and/or isolated. The *in situ* specimens show a significant double-wing preservation (LUKENEDER & TANABE 2002). Some have been crushed through sediment compaction. The problem of the correct correlation of isolated jaw elements and shells has been solved for several ammonite species within the Cretaceous (mostly Upper Cretaceous) genera *Aconeceras*, *Baculites*, *Damesites*, *Discoscaphites*, *Gaudryceras*, *Hoploscaphites*, *Jeletzkytes*, *Karsteniceras* (Fig. 4), *Menuites*, *Placenticeras*, *Phyllopachyceras*, *Polyptychoceras*, *Reesidites*, *Rhaebdoceas*, *Scalarites*, *Scaphites*, *Sciponoceras*, *Supptychoceras*, *Tetragonites*, *Tragodesmoceratoides* and *Yezoites* (KANIE et al. 1978; LEHMANN 1978; TANABE et al. 1980; KANIE 1982; SUMMESBERGER et al. 1996; TANABE & FUKUDA 1999; LUKENEDER & TANABE 2002; TANABE & LANDMAN 2002).

Low energy on the sea floor (absence of bottom currents) and dysaerobic conditions, which prevented predators from isolating the shells from the jaw apparatuses, led to the extraordinary preservation of the ammonite conch-jaw association. These exceptional preservational features are typical for 'Konservat-Lagerstätten' or 'Stagnate' (SEILACHER et al. 1976), which always show exceptional preservation, either of articulated hard parts or soft body preservation.

According to the interpretations of the authors cited above, the aptychi described herein are ammonite lower jaws. The positions of the lower jaw in the body chamber of the ammonite *Karsteniceras* clearly indicate that the dead ammonite bodies were not subjected to long post-mortem drift but rapidly became waterlogged and sank to the sea floor. This interpretation is consistent with geochemical, sedimentological and faunal data on the *Karsteniceras* horizons.

A similar isochronous *Karsteniceras* mass-occurrence was detected by LUKENEDER (2005d) approximately 150 km to the east at the Sparbach section in the Nappe (Lower Austria, Northern Calcareous Alps). It is located in the Frankenfels-Lunz Nappe System (Höllenstein Unit) within the Flössel Syncline. The distinct *Karsteniceras* occurrence appears to be the lateral continuation of the lower Barremian KB1-A *Karsteniceras* level.

Hochkogel section

Lower Cretaceous ammonoids were collected at the Hochkogel locality in the southernmost part of the Reichraming Nappe (Ebenforst Syncline, Northern Calcareous Alps; see LUKENEDER 2005a; Fig. 5). The cephalopod fauna sampled from marly parts of the Rossfeld Formation indicates upper lower Valanginian age. The ammonoid fauna comprises 7 different genera, each apparently represented by 1 or 2 species. The occurrence at the Hochkogel section is dominated by *Bochianites* (49%), *Ptychophylloceras* (18%) and *Haploceras* (18%). Ancyloceratids (represented only by bochianitids) are the most frequent component. Ammonitids and phylloceratids are roughly balanced (each about 20%). Lytoceratids are represented with below average values (7 %). A single deepwater nautiloid and 2 belemnite guards complete the cephalopod fauna. Brachiopods, bivalves and gastropods make up the main components of the benthic macrofauna (Fig. 5).

The deposition of the limestones in this area occurred in an unstable environment. Gravitational transport of different sediments and fragmented cephalopod specimens is assumed for the accumulated layers from the source area (situated to the south). The cephalopod fauna consists solely of Mediterranean elements.

The tectonically strongly deformed Lower Cretaceous sediments of the Ebenforst Syncline do not necessarily create the perfect conditions for excellent preservation of ammonoids (LUKENEDER 2005a). The macrofauna, as already stated, is represented especially by ammonoids. The whole section yielded about 800 ammonoids (includes fragments). The ammonoid moulds are restricted to the limestone beds. No ammonoids were found within the encompassing sandstone layers. The latter were formed by turbidity currents, show gradation and, on their top, plant debris. Some specimens (e.g. *Ptychophylloceras*) described from the Hochkogel show exceptional shell preservation (Fig. 5). The accompanying invertebrate fauna (LUKENEDER 2005a) consists of nautiloids, lamellaptychi, echinoderms (*Phyllocrinus*), brachiopods (*Triangope*) and bivalves (e.g. inoceramids and others; Fig. 5).

The stratigraphic investigation of the ammonoid fauna revealed that the Hochkogel section comprises upper lower Valanginian sediments of the *Busnardoites campylotoxus* and *Tirnovella pertransiens* zones and belongs exclusively to the Mediterranean Province. No descendants of the Boreal Province are observed at the Hochkogel section.

The following Mediterranean genera are observed with *Phylloceras*, *Ptychophylloceras*, *Ptychophylloceras*, *Lytoceras*, *Leptotetragonites*, *Haploceras* and *Bochianites* (Fig. 5). The ammonoid assemblage, the abundance of *Bochianites neocomiensis*, and the occurrence of *Haploceras extracornutum* hint at the lower Valanginian *Busnardoites campylotoxus* and *Tirnovella pertransiens* ammonite zones. Sorting, packing due to sedimentological or biological effects, and alignments or concentration due to transport or bottom currents can be observed. Thus, the analysis of the macrofauna and the sedimentological data support the interpretation of a highly dynamic palaeoenvironment on the slope to basin.

The suggested palaeogeographic position of the studied section indicates an influence of turbiditic redeposition ('debris flow') and an allochthonous origin of the fragmented ammonoids collected. The shell transport took place via 'mudflows' after the embedding in the sediment, as is reflected in the different alignments of the ammonoid shells and fragments within the sediment. The badly preserved, fragmented specimens within the marly limestone layers were apparently transported from a nearby, more shallow area such as that situated to the south, where they had been deposited primarily. The fragmentation and the diverse orientations of the ammonoid specimens within the sediment furnish evidence for a post-mortem turbidity-flow transport of the shells (LUKENEDER 2005a).

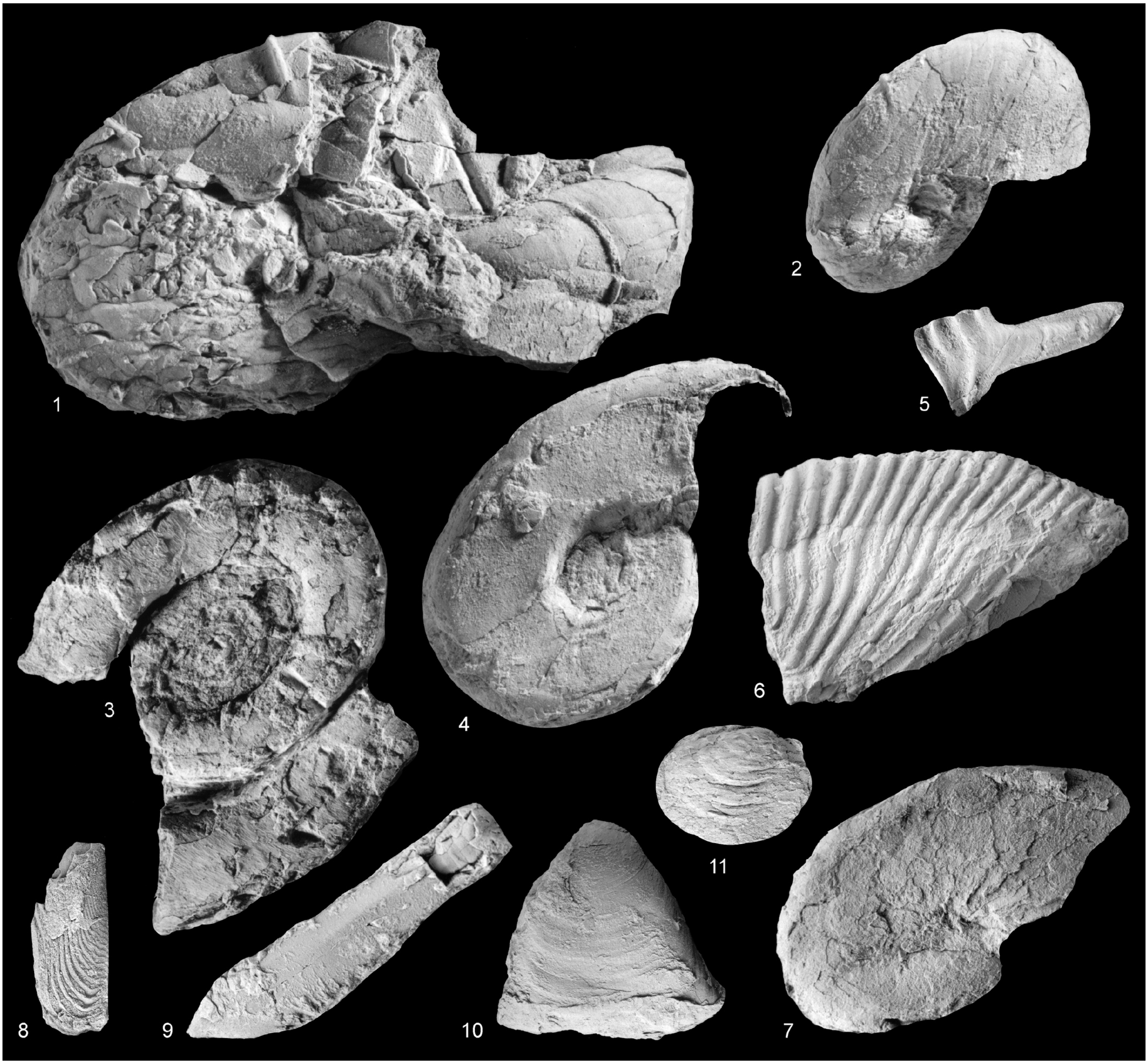


Fig. 5: Ammonites from the lower Valanginian Hochkogel section (Rossfeld Formation). **1**: *Ptychophylloceras ptychoicum* (QUENSTEDT), 2004z0116/ 0001. **2**: *Ptychophylloceras ptychoicum* (QUENSTEDT), 2004z0116/ 0002. **3**: *Leptotetragonites* cf. *honnoratianus* (D'ORBIGNY), 2004z0116/0009. **4**: *Haploceras grasianum* (D'ORBIGNY), 2004z0116/0010. **5**: Microconch lappet of *Neocomites* sp. (D'ORBIGNY), 2004z0116/0017. **6**: Fragment of a body chamber of an indet neocomitid ammonite, 2004z0116/0019. **7**: Nautiloid, 2004 z0116/0021. **8**: *Lamellaptychus* sp., 2004z0116/0025. **9**: Belemnite rostrum, 2004 z0116/0026. **10**: Bivalve, 2004z0116/0027. **11**: The brachiopod *Triangope* sp., 2004z0116/0028. All specimens are in natural size and coated with ammonium chloride before photographing.

The ammonoid beds are accompanied by layers showing orientated 'autochthonous' straight ammonoid shells (e.g. *Bochianites*) on bedding planes. Thus, for the specimens concentrated in such thin layers, a reorientation due to bottom currents is probable. Note that caution should be exercised when applying the terms autochthonous and allochthonous in cephalopods.

The Hochkogel was additionally analyses on the chronostratigraphical significance of its lower Valanginian calpionellid association (LUKENEDER & REHÁKOVÁ 2007). Early Cretaceous calpionellid samples were collected at the ammonoid-bearing Hochkogel locality in the southern most part of the Reichraming Nappe (Ebenforst Syncline, Northern Calcareous Alps). The microfossil fauna sampled from limestone parts of the Rossfeld Formation indicates an early Valanginian age. The standard *Calpionellites* Zone (with *Calpionellites darderi* and *Calpionellites major* subzones) coincides with

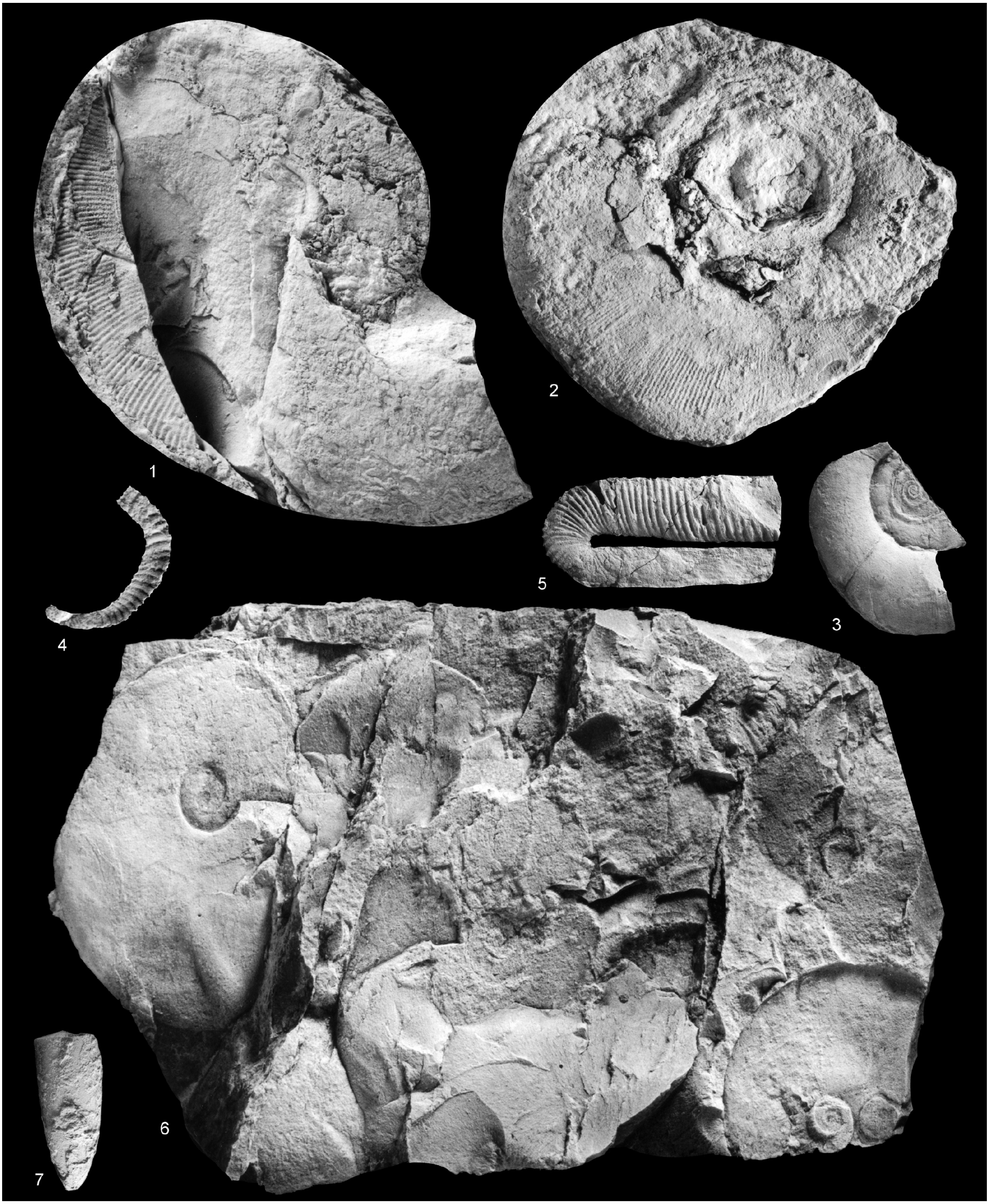


Fig. 6: Ammonites from the lower Barremian Hirner section (Schrambach Formation). **1**: *Phylloceras* (*Hypophylloceras*) *serum* (OPPEL), 2003z0045/0001. **2**: *Lytoceras subfimbriatum* (D'ORBIGNY), 2003z0045/0004. **3**: *Protetragonites* aff. *crebrisulcatus* (UHLIG), 2003z0045/0005. **4**: *Karsteniceras* cf. *ternbergense* (LUKENEDER), 2003z0045/0008. **5**: *Hamulina lorioli* (UHLIG), 2003z0045/0007. **6**: Accumulation of *Barremites* (*Barremites*) cf. *difficilis* (D'ORBIGNY), 2003z0045/0006. **7**: Belemnite, 2003z0045/0009. All specimens are in natural size and coated with ammonium chloride before photographing.

the lower Valanginian ammonoid zones of *Busnardoites campylotoxus* and *Tirnovella pertransiens*. The deposition of the limestones in this area occurred in an unstable environment disturbed by gravitational transport which accounts for the different sedimentary components and accompanying fossils in the accumulated layers, transported from a source area situated to the south.

The stratigraphic investigation of the microfauna revealed that the Hochkogel section comprises lower Valanginian deposits of the *Calpionellites* Zone (*C. darderi* and *C. major* Subzones), which corresponds to the *Busnardoites campylotoxus* and/or *Thurmannia pertransiens* ammonoid zones. The importance of this small microfossil fauna is that it enables dating of the sandstones of the Rossfeld Formation, which are normally barren of macro- and microfossils. Only thin limestone layers, intercalated in a sandstone interval of the Rossfeld Formation, yielded microfossil faunas. Based on the microfossil investigation, a better defined age could be detected, leading to a change from early late Valanginian (LUKENEDER 2005a) to a late early Valanginian (LUKENEDER & REHÁKOVÁ 2007).

Thirty two thin sections were examined from beds 1 and 3, which are formed of several different layers (A, B, C). Each of these could be further subdivided by the microfossil content with *Praecalpionellites*, *Calpionellites*, *Calpionella*, *Calpionellopsis*, *Tintinnopsella*, *Lorenziella*, *Remaniella*. The calpionellid fauna is accompanied by the following calcareous dinoflagellate genera *Cadosina* and *Colomisphaera*. The macrofauna is represented especially by ammonites.

The entire section yielded about 800 ammonites (including fragments; LUKENEDER 2005a). The ammonite moulds are restricted to the limestone beds. No ammonoids were found within the enclosing sandstone layers. The latter were deposited by turbidity currents, show gradation and, on their top, plant debris. Sorting or packing of fossil components due to sedimentological or biological effects, and alignments or concentration due to transport or bottom currents were observed. The macrofauna and the sedimentological data support the interpretation of a highly dynamic palaeoenvironment on the slope. The suggested palaeogeographic position of the section studied indicates an influence of turbiditic redeposition ('debris flow') and an allochthonous origin of the fragmented ammonoids collected.

Hirner section

An early Barremian ammonoid fauna from the Lower Cretaceous Schrambach Formation of the Schneeberg Syncline (Reichraming Nappe, Northern Calcareous Alps) yielded 8 genera, each represented by 1 or 2 species (LUKENEDER 2004d; Fig. 6). The exclusively Mediterranean ammonoids are dominated by Barremites (54.2%) of the Ammonitina, followed by the Lytoceratina (22.9%), Phylloceratina (12.5%) and *Karsteniceras* (10.4%) from the Ancyloceratina.

The macrofauna is represented especially by ammonoids. The whole section yielded about 48 ammonoids. Due to the preservation (moulds) of the cephalopods and the lithologic character of the Schrambach Formation, collecting and preparing ammonoids is difficult. The stratigraphic investigation of the ammonoid fauna revealed that the Hirner section comprises uppermost lower Barremian sediments of the *Moutoniceras moutonianum* Zone, and belongs exclusively to the Mediterranean Province. The association indicates that the cephalopod-bearing beds in the Formation belong to the latest early Barremian (*Moutoniceras moutonianum* ammonoid Zone; according to the Lower Cretaceous Ammonite Working Group; REBOULET et al. 2009).

The occurring cephalopods are: *Lytoceras subfimbriatum*, *Protetragonites* aff. *crebrisulcatus*, *Phylloceras serum*, *Phyllopachyceras infundibulum*, *Sowerbyceras ernesti*, *Barremits* (*Barremites*) cf. *difficilis*, *Hamulina lorioli* and *Karsteniceras* cf. *ternbergense* (Fig. 6). Although *Moutoniceras moutonianum* is missing, the typical association hints to a latest early Barremian age (LUKENEDER 2004d).

Sorting and packing due to sedimentological or biological effects, and alignments or concentration due to transport or bottom currents, cannot be observed. The analysis of the macrofauna and the sedimentological data support the interpretation of a palaeoenvironment on the outer shelf to slope.

The presented paper is a further step toward correlating rare Barremian faunas (e.g. layers of ammonoid occurrences) in Lower Cretaceous sediments within the Northern Calcareous Alps. Most of the ammonoids found at the Hirner section were apparently abundant or accumulated in few beds over the whole section (e.g. *Barremites*-abundance Zone, see LUKENEDER 2004d). Such beds show extraordinary abundance of more or less a single species (LUKENEDER 2003a). This was investigated on bedding planes from the Hirner section. The main future investigation topics concerning these ammonoid abundance zones and biohorizons within the above-described framework will be the palaeoecological, palaeobiogeographic and biostratigraphic development of Lower Cretaceous ammonoid beds within the Northern Calcareous Alps.

Eibeckgraben section

Ammonoids of Early Cretaceous age were collected at the Northern Calcareous Alps in the southernmost

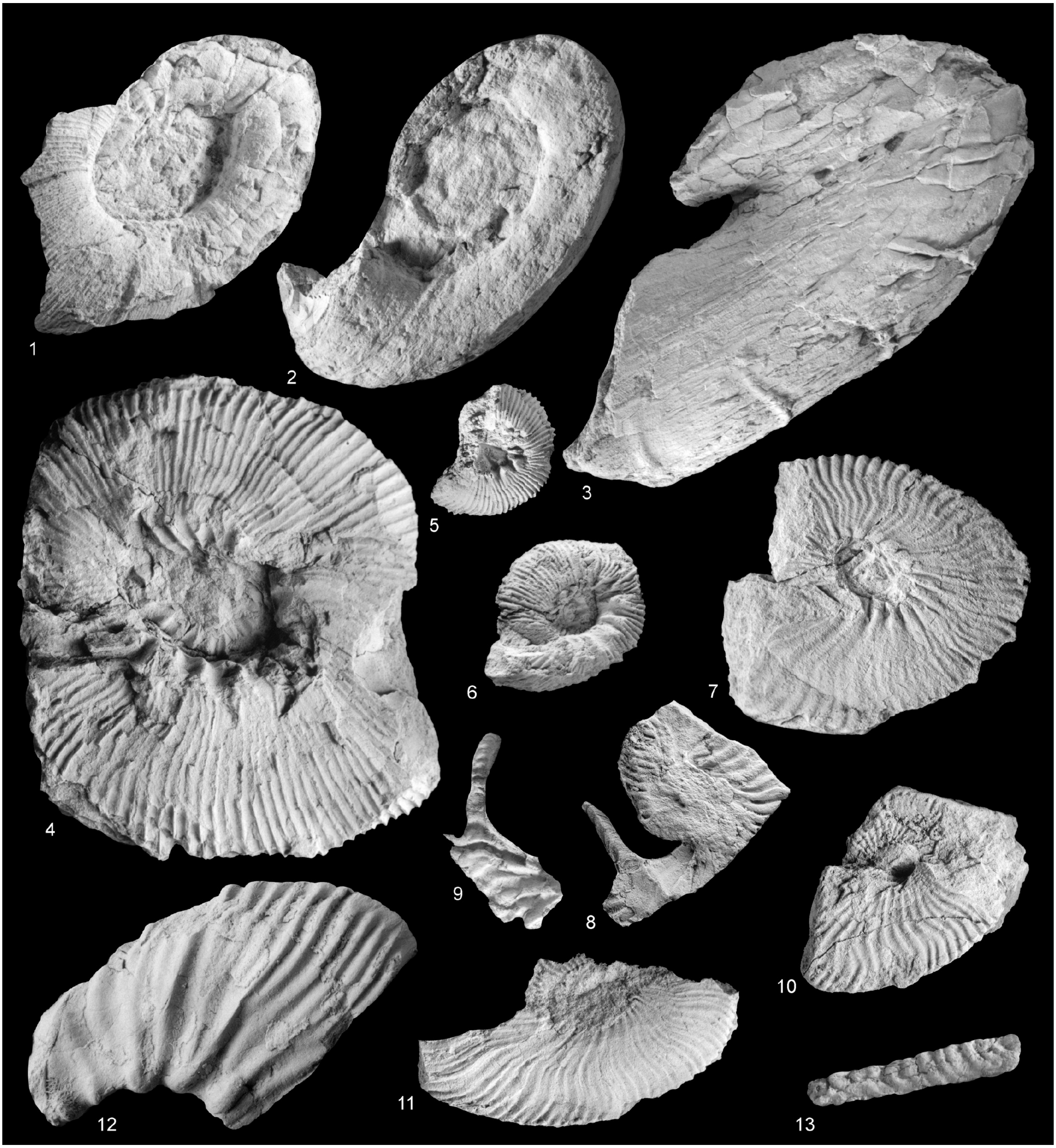


Fig. 7: Ammonites from the upper Valanginian Eibeck Section (Rossfeld Formation). **1**: *Lytoceras subfimbriatum* (d'Orbigny), 2004z0080/0021. **2**: *Leptotetragonites* cf. *honnoratianus* (d'Orbigny), 2004z0080/0019. **3**: *Ptychophylloceras ptychoicum* (Quenstedt), 2004z0080/ 0022. **4**: *Olcostephanus guebhardi* (Kilian), 2004z0080/0005. **5**: *Olcostephanus guebhardi* (Kilian), 2004z0080/0006. **6**: Olcostephanus guebhardi (Kilian), 2004z0080/0007. **7**: *Neocomites teschenensis* (Uhlig), 2004z0080/0008. **8**: *Neocomites teschenensis* (Uhlig), 2004z0080/0009. **9**: *Neocomites teschenensis* (Uhlig), 2004z0080/0010. **10**: *Neocomites teschenensis* (Uhlig), 2004z0080/0011. **11**: *Neocomites neocomiensis* (d'Orbigny), 2004z0080/0015. **12**: The boreal ammonite *Prodichotomites* sp., adult specimen, 2004z0080/0016. **13**: *Bochianites neocomiensis* (d'Orbigny), 2004z0080/0026. All specimens are in natural size and coated with ammonium chloride before photographing.

Fig. 8: The belemnite *Conobelus pseudoheres* (Lukeneder) from the upper Valanginian Eibeck Section (Rossfeld Formation). **1**: Holotype, lateral view, 2004z0046/0001. **2**: Dorsal view of the same specimen. **3**: Lateral view of the same specimen. Specimens in natural size.

part of the Reichraming Nappe (Ebenforst Syncline; Lukeneder 2004c). The cephalopods (Fig. 7), which derive from the Rossfeld Formation indicate an earliest late Valanginian age (*Saynoceras verrucosum* Zone; *Karakaschiceras pronecostatum* Subzone).

The deposition of the marly limestones and marls in this interval occurred during unstable environmental conditions which led to a mixed autochthonous/allochthonous ammonoid fauna. During the course of this study, 129 ammonoids and 4 lamellaptychi were examined. The ammonoid fauna comprises 10 different genera, each apparently represented by 1–2 species. Ammonitina are the most frequent components (89%, represented by *Haploceras*, *Neocomites*, *Oosterella*, *Eleniceras*, *Olcostephanus*, *Prodichotomites*; Fig. 7), followed by the lytoceratids (5%, *Lytoceras*, *Leptotetragonites*), the phylloceratids (5%, P*tychophylloceras*) and the ancyloceratids (1%, *Bochianites*). The cephalopod fauna consists of numerous Mediterranean elements (dominated by *Olcostephanus*) and scarce Boreal ammonoids (the latter represented by *Prodichotomites*). The described Prodichotomites provides the first evidence of Boreal ammonoids within the Northern Calcareous Alps during the Valanginian and moreover the southernmost occurrence of this genus so far.

The macrofauna of the Eibeck section is represented especially by ammonoids, belemnoids, aptychi and bivalves. The whole section has yielded 129 ammonoids. The poor preservation (mostly internal moulds, limonitic steinkerns) of the ammonoids and the lithologic character of the Rossfeld Formation makes the sampling difficult. The fauna can be assigned to the *Saynoceras verrucosum* Zone (*Karakaschiceras pronecostatum* Subzone) sensu Reboulet et al. (2009). It contains descendants of the Mediterranean Province and a single Boreal genus. According to the stratigraphic investigations the boreal ammonoid corresponds to the genus *Prodichotomites*. The described Boreal descendant *Prodichotomites* (Fig. 7) provides the first evidence of Boreal ammonoids within the Alpine region (Northern Calcareous Alps) during the Valanginian, and marks the southernmost limit of migration of the genus (Lukeneder 2004c).

The deposition of the marls took place during conditions of relatively stable water masses and high sedimentation rates but under unstable sedimentological

Fig. 9: Ammonites from the lower Aptian Traunkirchen section (Tannheim Formation). **1**: Left side view of *Procheloniceras* aff. *albrechtiaustriae* (Hohenegger). **2**: External view of the specimen. **3**: Right side view of the specimen. The specimen was coated with ammonium chloride before photographing. The natural size is 30 cm. No inventory number can be given since the original specimen is in property of Helmut Kreiseder (Department of the Upper Austrian Government). A cast of the specimen is stored at the Natural History Museum Vienna.

(e.g. turbidites, bottom morphology) conditions. The shells were transported within 'mudflows' following embedment in the sediment. The abundant olcostephanid specimens seem to have been redeposited from shallower shelf regions into a deeper shelf environment. The fauna of the Eibeck section is therefore interpreted as a mixed assemblage, comprising transported elements from the shallower shelf and autochthonous benthic and parautochthonous pelagic elements from the open sea. Different life habitats are assumed for males (microconchs) and females (macroconchs) of the genus *Olcostephanus*. Microconchs probably lived in the open sea, whereas the macroconchs dwelt in the shallower water of the lower shelf (Lukeneder 2004c).

The first Cretaceous belemnite preserved with the rostrum, slightly compressed phragmocone and part of the proostracum was described from the Lower Cretaceous (upper Valanginian) Rossfeld Formation (Eibeck, Reichraming Nappe of the Northern Calcareous Alps (Lukeneder 2005b). The rostrum has dorsal groove (alveolar furrow) typical of duvaliids, and its conical shape (round in transverse section outline), and the rounded apex allow its attribution to *Conobelus* Stolley, 1919. The species *Conobelus pseudoheres* Lukeneder, 2005b (Fig. 8) was introduced based on the unique features of the specimen, i.e. persistently parallel lateral sides throughout the rostrum and the conical, blunt outline at the apex. The ration between rostrum and phragmocone is 0.78; the distances between the calcitic septa of the anterior end of the phragmocone range from 3 to 5 mm. The proostracum is 0.02 mm thick. The apical angle is 32° and the alveolar angle (posterior end of the phragmocone) is 24°. The alveolus is 40 mm long, yielding a ratio between rostrum and alveolus of 1.86. The depositional history with its fast sedimentation along with absent/limited post-mortem transportation led to extraordinarily good preservation of the examined specimen.

The Early Cretaceous coleoid *C. pseudoheres* is preserved with almost its entire shell (Lukeneder 2005b; Fig. 8). The rostrum with its dorsal groove, the partly but three-dimensionally preserved pharagmocone and parts of the extremely rarely observed proostracum of the family Duvaliidae are preserved. This specimen represents the first published finding of an almost entire belemnite within Cretaceous sediments. The preservation of the belemnite furnishes evidence of fast burial and minimal or no post-mortem transport (on the seafloor) of the shell.

The investigation of the macrofossil assemblage and its taphonomy indicated a mixed autochthonous/allochthonous occurrence at the Eibeck section. The assemblage is composed of specimens derived from the local community and preserved in 'life-position' (or as an 'in-place assemblage') as well as of drifted or moved specimens (broken specimens). Re-deposition of the presented belemnite specimen through currents or turbidites can be ruled out based on the extraordinary preservation of fragile parts (e.g. phragmocone, proostracum). Compression and breakage of this *Conobelus* individual (phragmocone) through sediment pressure is assumed. The deposition took place under conditions of relatively stable water masses and a high sedimentation rate. New aspects of the morphology of Cretaceous belemnites are shown, taxonomic problems discussed, and additional nomenclature perspectives are given in LUKENEDER (2005b). The stratigraphic investigation of the cephalopod fauna revealed that the Eibeck section comprises lower upper Valanginian sediments of the *Saynoceras verrucosum* Zone.

Traunkirchen section

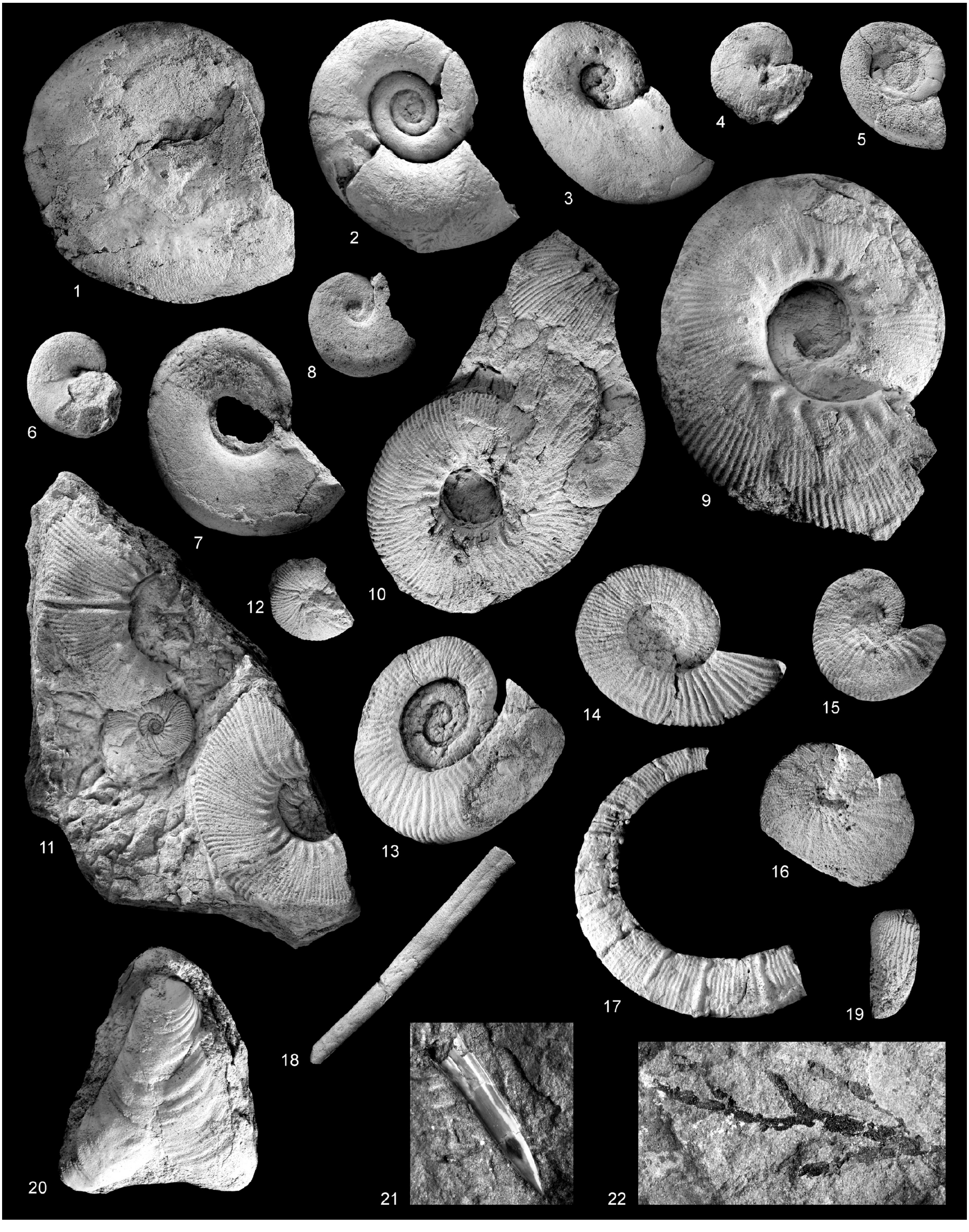
The only ammonite specimen (Fig. 9) from the Traunkirchen locality was found by Helmut KREISEDER (Department of the Upper Austrian Government) during the construction of the Traunkirchen tunnel in Upper Austria. The outcrop, in which the ammonite *Procheloniceras* was detected (Fig. 9), is no longer accessible. The characteristic ribbing, tuberculation and conch morphology enabled a systematic determination as *Procheloniceras* aff. *albrechtiaustriae* from the lower Aptian (LUKENEDER 2005c) The important and unique (for Upper Austria) ammonite from the Tannheim Formation is approximately 125 million years in age.

Kolowratshöhe section

Ammonoids of Early Cretaceous age were collected in the Kolowratshöhe section, which is located in the easternmost part of the Staufen-Höllengebirgs Nappe (Tyrolic Unit, Northern Calcareous Alps; LUKENEDER 2005e). The cephalopods, which occur in turbidite sandstones of the Rossfeld Formation, indicate a latest late Valanginian age (*Criosarasinella furcillata* Zone). The ammonoid fauna (483 specimens) comprises 13 different genera, each represented by one or two species. Ammonitina are the most frequent components (65%, represented by *Haploceras*, *Neocomites*, *Criosarasinella*, *Rodighieroites*, *Olcostephanus*, *Jeanthieuloyites*, Fig. 10), followed by the lytoceratids (17%, *Lytoceras*, *Leptotetragonites*, *Protetragonites*), the phylloceratids (7%, *Phylloceras*, *Phyllopachyceras*) and the ancyloceratids (11%, *Bochianites*, *Crioceratites*, *Himantoceras*). The ammonite genera and species were identified as *Phylloceras serum*, *Phyllopachyceras winkleri*, *Lytoceras subfimbriatum*, *Lytoceras sutile*, *Protetragonites* sp., *Haploceras* (*Neolissoceras*) *grasianum*, *Haploceras* (*Neolissoceras*) *desmoceratoides*, *Olcostephanus densicostatus*, *Neocomites praediscus*, *Neocomites subpachydicranus*, ?*Rodighieroites* sp., *Jeanthieuloyites* cf. *quinquestriatus*, *Criosarasinella furcillata*, *Crioceratites* sp., *Himantoceras* sp. and *Bochianites oosteri* (see LUKENEDER 2005e; Fig. 10).

Fig. 10: Ammonites from the upper Valanginian Kolowratshöhe section (Rossfeld Formation), with the dominant species *Olcostephanus densicostatus* (WEGNER). **1**: *Phylloceras serum* (OPPEL), 2005z0233/0002. **2**: *Lytoceras subfimbriatum* (D'ORBIGNY), 2005z0233/0003. **3**: *Lytoceras sutile* (OPPEL), 2005z0233/0004. **4**: *Phyllopachyceras winkleri* (UHLIG), 2005z0233/0006. **5**: *Protetragonites* cf. *quadrisulcatus* (D'ORBIGNY), 2005z0233/0007. **6**: *Phyllopachyceras* cf. *rogersi* (KITCHIN), 2005z0233/0009. **7**: *Haploceras desmoceratoides* (WIEDMANN), 2005z0233/0012. **8**: *Haploceras grasianum* (D'ORBIGNY), 2005z0233/0014. **9**: *Olcostephanus densicostatus* (WEGNER), M, 2005z0233/0015. **10**: *Olcostephanus densicostatus* (WEGNER), M, 2005z0233/0016. **11**: Accumulation of *Olcostephanus densicostatus* (WEGNER), M and m, 2005z0233/0022. **12**: *Jeanthieuolyites cf. quinquestriatus* (BESAIRIE), 2005z0233/0024. **13**: *Criosarasinella furcillata* (THIEULOY), 2005z0233/0027. **14**: *Criosarasinella furcillata* THIEULOY, body chamber, 2005z0233/0030. **15**: *Neocomites subpachydicranus* (REBOULET), 2005z0233/0032. **16**: *Neocomites praediscus* (REBOULET), 2005z0233/0034. **17**: *Crioceratites* sp., 2005z0233/0039. **18**: *Bochianites oosteri* (D'ORBIGNY), 2005z0233/0041. **19**: *Lamellaptychus* sp., 2005z0233/0043. **20**: *Triangope* sp., 2005z0233/0045. **21**: *Sphenodus* sp., shark tooth, 2005z0233/0046. **22**: *Brachyphyllum* sp., Coniferales, 2005z0233/0047. All specimens x0.5 and coated with ammonium chloride before photographing. M: macroconch, m: microconch.

The cephalopod fauna consists only of Mediterranean elements (dominated by *Olcostephanus*, microconchs and macroconchs, 231 specimens). The term '*Olcostephanus densicostatus* abundance Zone' was established for these abundance beds (LUKENEDER 2005e). The ammonoid specimens of the Kolowratshöhe are accumulated into 3 different layers within an interval of 30 centimetres of sandstone. The fauna of the Kolowratshöhe section is interpreted as a mixed assemblage, comprising allochthonous elements transported from the shallower shelf and parautochthonous pelagic elements from the open sea. The presence of abundant glauconite indicates low sedimentation rates in the source area, whereas the final deposition of the sandstones of the Rossfeld Formation took place during conditions of relatively high sedimentation rates but under the influence of turbidites and varying bottom morphol-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ogy. The allochthonous glauconite points to a shallow shelf environment as the primary source for the sandstones. This source area was interpreted as a land high and a shelf from which the sediments were delivered into basins of the Northern Calcareous Alps (e.g. Tyrolic Unit) to the north of the swell. The basin palaeogeography is interpreted as a submarine, northward-directed proximal/distal slope belonging to an uplifted area situated to the south of the basin.

The final deposition of the sandstones from the Kolowratshöhe took place during conditions of relatively high sedimentation rates. The sandstones of the Rossfeld Formation in this area consist mainly of turbidites. The source area was a subaerial high and a shelf from which the sediments were delivered into northern basins of the Northern Calcareous Alps. The high has been shown to extend above the sea-level as confirmed by findings of the land plant *Brachyphyllum* (Fig. 10). On the whole, the presence of glauconite indicates a low deposition rate in the source area (LUKENEDER 2005e). The lithological and mineralogical diagnostic findings point to an amalgamation of single turbidite beds after a decline or cessation of sedimentation. A cessation is strongly supported by the accumulation of glauconitic grains in single layers that separate single beds of glauconitic sandstones. The macrofauna of the Kolowratshöhe section is represented especially by ammonoids. The whole section yielded 483 ammonoids. Based on the presence of the index fossil *Criosarasinella furcillata*, the fauna can be assigned to the *C. furcillata* ammonoid Zone (*C. furcillata* Subzone). The ammonoid fauna contains only descendants of the Mediterranean Province.

The invertebrate fauna (e.g. ammonites and brachiopods) are accumulated in isolated single layers. The shells are aligned concentrated in particular levels and some show current-induced orientation. This applies both to straight shells (e.g. *Bochianites*) as well as coiled shells (e.g. *Lytoceras*, *Haploceras*, *Olcostephanus*). This points to orientation by currents (LUKENEDER 2005e). Additionally, accumulated small ammonoids and shell fragments in the body chambers of somewhat larger ammonoids supports the assumed effect of agglomeration and scavenging by currents. The accumulation of ammonoid layers (Fig. 10) indicates either deposition on site at short, favourable 'time-intervals', or to reworked accumulation-layers after turbiditic transport.

At least some of the abundant ammonoid specimens seem to have been redeposited from shallower shelf regions into a slope environment. The encrustation of larger smooth shell fragments by serpulids indicates a somewhat longer depositional history for such shells. This is interpreted as a sign for overgrowth of such secondary 'hardgrounds' uncovered by sediments, by the benthic organisms during lengthier exposure.

Most probably the encrustation took place already at the primary depositional area on the shelf. The very small number (14) of aptychi contrasts the very high (483) number of ammonoid specimens. Isolation took place either through transport (and therefore different behaviour in the water column) or through current-induced grain differentiation during accumulation. The latter scenario leads to different places of deposition for these two cephalopod elements of the same animal (LUKENEDER 2005e). Based on all these data, the fauna of the Kolowratshöhe section is interpreted as a mixed assemblage, comprising transported elements from the shallower shelf (allochthonous) along with more parautochthonous pelagic elements (olcostephanids) from the open sea.

Conclusions

Distinct ammonite faunas derive from limestones, marls and sandstones of well known tectonical nappes from the Northern Calcareous Alps of Upper Austria. The specimens were collected during the last two decades in the Ternberg Nappe, Reichraming Nappe, Staufen-Höllengebirgs Nappe, and the Langbath Unit. The main sections are from north to south the KB1-A Klausrieglerbach 1 section (Schrambach Formation), the KB1-B Klausrieglerbach 2 section (Schrambach Formation), the Hirner section (Schrambach Formation), the Eibeck Section (Rossfeld Formation), the Hochkogel section (Rossfeld Formation), the Traunkirchen section (Tannheim Formation) and the Kolowratshöhe section (Rossfeld Formation).

During the study, thousands of ammonite specimens were collected, prepared and described. More than 100 species of Valanginian to Barremian cephalopods (ammonites and belemnites) were detected and several new species introduced, such as the ammonite *Karsteniceras ternbergense* (named after the village Ternberg in Upper Austria) and the belemnite *Conobelus pseudoheres*. Palaeontological studies on the Lower Cretaceous ammonite material increased the knowledge on palaeoceanography and palaeoenvironments prevailing during Cretaceous times in the Upper Austrian Northern Calcareous Alps. The Lower Cretaceous ammonite fauna is dominated by Mediterranean faunal elements accompanied by a single Boreal member, *Prodichotomites*. Additional ammonite collections will be carried out in the future to determine the exact position of stage-, zone-, and subzone-boundaries. These studies will include palaeomagnetic, isotope and geochemical analyses along with a detailed biostratigraphy based on micro- and nannofossils.

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